Study Questions Exam 2

1. The height of capillary rise in a tube of radius X is Y. What is the rise in a tube of radius 0.1X?

Height of rise is inversely proportional to tube radius. H / Y = X / 0.1X, so H = 10Y.

2. What are the components of soil water potential under saturated conditions? Under unsaturated conditions?

Saturated, gravitational + pressure + osmotic; unsaturated, gravitational + matric + osmotic.

3. In the absence of a semipermeable membrane, does osmotic potential affect water flow in soil?

No. That's why only gravitational + pressure (or matric) potentials affect flow in saturated (or unsaturated) soil. Osmotic potential will, however, affect flow to roots.

4. What two soil water variables are related in a soil moisture characteristic curve?

Water content and matric potential (also called tension or suction).

5. Given a soil moisture characteristic curve for a clay and a sand, distinguish between the two soils. Which has the higher water content at saturation? Which shows the steeper decrease in water content with decreasing (more and more negative) matric potential? How is this behavior related to pore size distribution?

Since the bulk density of a clay is typically less than the bulk density of a sand, there is typically greater pore space in a clay. Consequently, a clay has higher water content at saturation (0 matric potential). Furthermore, a clay has a wider distribution of pore sizes than a sand, which mostly has large pores. Thus, when a sand drains from saturation under increasing tension (more and more negative matric potential), its water content decreases quickly whereas the decrease in water content of a clay under increasing tension is less steep.

6. What effect does structure have on the soil moisture characteristic curve? Distinguish between a curve for a structured and compacted soil.

Structure may increase total pore space and does increase the amount of macroporosity (fraction of pore space composed of large pores). Thus, a structured soil gives a moisture characteristic curve that has higher water content at saturation and steeper decrease in water content with increasing tension than a compacted soil (which has less macroporosity).

7. The soil moisture characteristic curve shows different branches depending on whether the soil is absorbing water or draining. What is the phenomenon called? Distinguish which branch is for absorption and which for drainage. Give a reason for this behavior.

Hysteresis. For the same matric potential, the moisture characteristic curve for a soil that is draining from saturation shows higher water content than the same soil when it is wetting. The phenomenon is thought to be due to several factors, including “ink bottle” shape of pores. When a water-filled, bulbous pore is subject to drainage, it will not empty until the matric potential becomes sufficiently negative that a pore of the neck radius empties. On the other hand, the same pore will not fill when wetting until a less negative matric potential, equal to that associated with the larger radius interior of the pore, is reached.

8. A 50 cm^3 core sample of moist soil weighed 68 g. After drying at 105 C for 24 h it weighed 60 g. What was the gravimetric water content of moist soil? The volumetric water content?

GW = 8 g / 60 g = 0.13 VW = [8 g / (1.0 g cm^{-3})] / 50 cm^3 = 0.16

9. Water flow, whether saturated, unsaturated or vapor phase, is always from higher to lower potential (True / False)?

10. Work a simple saturated flow problem, like from lab.

See examples for lab exam.

11. What effect does texture have on the saturated hydraulic conductivity? What effect does structure have? Explain in terms of pore sizes.

Saturated hydraulic conductivity increases with increasing coarseness of texture. Conductivity of a structured soil is typically greater than in a soil without structural units. In both cases, the effect is due to increasing fraction of large pores, either in increasing coarseness or presence of large interaggregate pores.

12. Is matric potential more important than gravitational potential in causing unsaturated water flow?

Yes. This can easily been seen using the approximate relationship, 1 bar = 1000 cm water. For example, if the surface soil is fully saturated (matric potential = 0 bar) and soil 10 cm below is at field capacity (matric potential = -0.3 bar), the difference in total potential, surface minus subsurface, is [0 cm (gravitational potential) + 0 cm (matric potential)] – [-10 cm (gravitational potential) + (-300) cm (matric potential)] = 310 cm. Thus, the gradient in water potential, difference in potential divided by distance, 31, is predominantly due to the difference in matric potential.

13. Why does the unsaturated hydraulic conductivity decrease with decreasing water content?

There are 3 main reasons: 1) the water-filled cross section decreases with decreasing water content ; 2) the path through which water flows increases with decreasing water content; and 3), most importantly, the size of the pores that remain filled with water decreases with decreasing water content. Recall that resistance to flow increases with decreasing pore radius (small pore area compared to perimeter).

14. The direction of vapor phase water movement in soil is from

Lower to higher vapor pressure	True or False
Cold soil to warm soil	True or False
Saline to nonsaline soil	True or False
Low to higher matric potential	True or False

Water vapor moves down a vapor pressure gradient so that since vapor pressure is greater under warm temperature and above nonsaline water, the first through third statements are false. Furthermore, when the soil is very dry, soil solids hold liquid water with such tenacity that its vapor pressure is reduced.

15. What effect does a layer of clay under coarser texture soil have on water movement? Conversely, what effect does a layer of sand under finer texture soil have on water movement?

An underlying clay layer with its comparatively low hydraulic conductivity will slow water movement. Interestingly, something of the same thing occurs when water moving through a fine texture soil encounters a layer of coarse material. Obviously, the coarse layer cannot accelerate water flow since this is controlled by the hydraulic conductivity of the overlying fine texture soil. However, the coarse layer does have an effect. The water in the fine pores of the overlying fine texture soil is held at too great of tension (too negative matric potential) to enter the large pores of the underlying coarse soil. Therefore, water tends to build up above the coarse soil and will not enter it until the tension on the water in the fine soil becomes much lower. It is in this way that the sand layer temporarily retards water flow.

16. What is *field capacity*? Since water is soil is always moving, what is really meant by this term?

Field capacity is water content at approximately -0.3 bar tension (also this value of water tension). The concept stems from the observation that water drainage becomes quite slow at about -0.3 bar tension and, from a practical standpoint, most of the water held in the soil at this tension will not drain deeper into the soil and, therefore, be available to plants.

17. Define *wilting point, hygroscopic coefficient,* and *plant-available water*.

Wilting point is approximately -15 bar. This is the approximate tension (matric potential) below which plants cannot extract water sufficient to meet transpirational demand. Hygroscopic coefficient is approximately -30 bar, the tension of water in air-dry soil. Plant-available water is water in between field capacity and wilting point.

18. What is *gravitational water* and why isn't it also considered *plant-available*?

Gravitation water is water in the soil at tensions above field capacity. Most of it will drain below the root zone and so will not be available for plant uptake.

19. What are *capillary water* and *hygroscopic water*?

Capillary water is water held in capillaries (soil pores). Like these other older, qualitative terms, it is not a precise concept. Think of it as any soil water present when the soil is not air-dry. In an air-dry soil, water is present only as thin, adsorbed films on solid particles. In a somewhat wetter soil, the tiniest of pores (tiniest of capillaries) will be water-filled.

20. Explain the effect of soil texture on plant-available water. What effect does organic matter have on plant-available water?

See figures in lecture synopsis. Water content at field capacity increases with increasing fineness of texture. Similarly, water content at the wilting point increases with increasing fineness of texture. However, these two curves at first diverge (beginning with sand texture, going to loamy sand) but later tend to converge (heading to clay texture). Therefore, at an intermediate texture (silt loam) the difference between field capacity and wilting point is greatest, or, in other words, plant-available water is greatest.

For a set texture, however, both water content at field capacity and wilting point continue to diverge with increasing organic matter content –plant available water increases with increasing organic matter content.

21. Draw a diagram that shows the water movement processes that comprise the field water cycle.

See figure in lecture synopsis.

22. Explain why all rainfall at an intensity greater than the saturated hydraulic conductivity of a soil may, for some period of time, infiltrate the soil but with continued rainfall, infiltration slows and surface ponding develops.

Imagine the surface (~ 1 cm) soil is saturated but the soil 10 cm below the surface is dry. In this situation there is a huge water potential gradient (see discussion # 12). With further infiltration, however, the water content 10 cm below the surface increases and the tension on it decreases so that the water potential gradient is reduced. According to Darcy's Law, it is possible to have water flow greater than the saturated hydraulic conductivity provided that the water potential gradient is large. Thus, it is possible to have infiltration match rainfall intensity for a period of time even though rainfall intensity exceeds saturated hydraulic conductivity. However, the water potential gradient will decrease to the point that rainfall intensity exceeds infiltration, resulting in ponding and runoff.

23. What effect does the soil surface hydraulic conductivity have on infiltration? How does formation of a surface crust affect infiltration?

A thin layer of low hydraulic conductivity soil at the surface (a crust) will limit the rate of infiltration, not a good thing.

24. What effect does soil water content at the onset of infiltration have on infiltration?

See discussion # 12 and # 22. Higher water content at onset of infiltration means smaller gradient in water potential at the soil surface. Thus, if rainfall intensity is greater than saturated hydraulic conductivity, the period of time during which infiltration rate can match rainfall intensity is shorter and there is more runoff.

25. What meteorological factors influence combined evaporation and transpiration (evapotranspiration)?

Solar radiation, water vapor pressure (humidity), wind speed and temperature.

26. Evaporation from soil may proceed at a constant rate that is determined by environmental conditions and meet demands set by external evaporativity. But after the soil sufficiently dries, the rate of evaporation tapers off. Explain why.

The answer is similar to # 22. Consider a uniformly wet soil. As water evaporates from the surface, a large gradient in water potential –higher just below the surface and much lower at the surface—is established. This gradient is sufficient to bring water from deeper in the soil to the surface where it evaporates. But as evaporation continues, the soil dries to a deeper depth and the gradient in water potential decreases (the distance over which a large difference in water potential exists becomes longer). Eventually, the decreasing water potential gradient is insufficient to move water to the surface fast enough to meet demands set by external evaporativity and the rate of evaporation decreases.

27. How do mulches (including crop residue left on the surface by conservation tillage) reduce evaporative losses of soil water?

They reduce solar radiation, gradient in water vapor pressure (extending from the soil surface upward into the air), wind speed at the soil surface and temperature –all factors that favor evaporation.

28. What effect does shading the soil surface by a plant canopy have on the relative contribution of transpiration and evaporation to overall evapotranspiration?

Decreases evaporation, therefore, increases contribution of transpiration.

29. Is percolation more common when infiltration exceeds evapotranspiration?

Yes. Water that infiltrates the soil may either move downward or be lost by evaporation and transpiration. Thus, if evapotranspiration is less than infiltration, the tendency is for water to percolate downward.

30. What is the potential effect of macropore flow on ground water quality?

Macropore flow (or by-pass flow) is an avenue for rapid movement of water in the soil. Furthermore, flow through macropores has much less contact with soil solids than flow through micropores. Consequently, potential ground water contaminants move quickly, with little adsorption to retard them, during macropore flow. Fortunately, macropore flow is usually a small fraction of total water flow in soil (other than very sandy soils).

31. What is a *capillary fringe* and why does it exist?

Capillary fringe refers to a water-saturated zone in the soil in which the water is at less than atmospheric pressure (under tension or negative matric potential). It exists because soil pores are sufficiently small that they remain filled with water under small tension.

32. Is the *vadose zone* saturated or unsaturated?

It is unsaturated by definition.

33. What is the purpose of surface drainage? Subsurface drainage?

The purpose of both is to improve aeration in the root zone but it has the additional benefits of allowing the soil to warm faster in the spring and allowing sooner access by equipment after heavy rainfall.

34. What is the importance of drainage with irrigation?

Though not discussed in class, it is important to have good drainage when using irrigation so as to avoid accumulation of salts in the root zone. If irrigation water did not drain but moved upward due to surface evaporation, the load of salt in each irrigation event would stay in the root zone, ultimately creating a saline soil (discussed later in course). When drainage is good, more water than is needed by the crop can be applied so salt residue from the previous irrigation is leached below the root zone as water percolates downward.

35. Name the three general types of irrigation systems. List principal advantages and limitations of each.

Surface	Low cost but non-uniform wetting and inefficient water use
Sprinkler	Higher cost but uniform wetting and efficient water use
Drip	High cost and maintenance but most efficient water use

36. Compare the composition of soil air to that of the atmosphere.

Compared to the above ground atmosphere, soil air is typically lower in oxygen, higher in carbon dioxide and higher in water vapor.

37. Why is gas diffusion much smaller in soil than in air? What effect does high soil moisture have on gas diffusion in soil?

It must pass through soil pores, along whatever circuitous path they take, often interrupted by water-filled pores. Since the rate of gas (molecules) diffusion through water is much slower than through air, gas diffusion in a wet soil is much slower than in a dry soil.

38. What happens to the redox potential when the oxygen content of soil decreases?

It decreases.

39. Under anaerobic conditions, the activity of aerobic microbes drops off and the activity and populations of anaerobic microbes greatly increases. What do anaerobic microbes use as terminal electron acceptors in respiration? Give a couple of examples. Arrange in approximate order of decreasing redox potential.

Different anaerobic organisms use nitrate (NO_3^-), oxidized iron (Fe^{3+}), oxidized manganese (Mn^{4+}), sulfate (SO_4^{2-}) and carbon dioxide (CO_2) as terminal electron acceptors in respiration. When oxygen is depleted the Eh (redox potential) is favorable for those organisms that use nitrate to flourish, and as they do the Eh is further reduced and nitrate depleted. Then come into play those anaerobic organisms that use the other terminal electron acceptors in the sequence given above.

40. What effect does soil organic matter have on the tendency of water-logged soils to become strongly anaerobic?

All heterotrophic microorganisms, including anaerobes, need organic matter for energy and as a carbon source. With little organic matter there would be little metabolic activity, consuming oxygen or any of the other terminal electron acceptors (# 39). Consequently, water-logged conditions would not result in strongly anaerobic conditions without the presence of organic matter.

41. List two ill-effects of anaerobic conditions on plant growth.

Less energy for growth, toxic products, reduced nutrient availability and others.

42. List a few benefits of wetland soils.

For those of us in South Louisiana, protection from coastal flooding is a plus. But even in upland areas, wetlands often control and limit downstream flooding. Other important functions include benefit on water quality (for example, reduction in nitrate concentration due to anaerobic respiration) and wildlife habitat / diversity. The latter is important to our use of wetlands for recreation and fisheries.

43. On what three general criteria are wetland soils delineated and boundaries drawn with respect to adjacent non-wetland soils?

Surface hydrology, plants and indicators of hydric soils.

44. Roughly define *hydric soils*.

Soils wet sufficiently long when the temperature is high that anaerobic conditions exist.

45. What are the usual colors expected for a well-drained soil? A poorly-drained soil?

Red, orange and brown for well-drained soil but yellow and especially gray, even bluish, for poorly-drained soil. The gray to blue color, due to chemically reduced iron (Fe^{2+}) characterizes gley. Poorly-drained soils also typically contain more organic matter than well-drained soils. Thus, poorly-drained soils may be darker.

46. List and briefly discuss three redoximorphic (colors associated with presence, absences or distribution of oxidized and reduced iron) features of hydric soils.

Gley	Iron in chemically reduced form (see # 45)
Iron concentration	Reduced iron is re-oxidized to Fe^{3+} and segregates to form reddish or brownish mottling against a gray or lighter colored matrix
Iron depletion	Iron that is solubilized to Fe^{2+} is swept from the soil by water moving through the soil, leaving the soil light in color.

47. Although dark colored soils absorb more solar radiation than light colored soils, warming may be slower. Why?

See # 45. Although darker in color, the soil may be wet. Higher water content gives a higher specific heat and increased evaporation, both tending to keep a soil cooler.

48. How do slope and aspect affect soil temperature?

The orientation of the (bare) soil surface with respect to incident solar radiation controls the intensity of radiation at the surface (perpendicular to radiation, greatest).

49. In what three ways does soil water affect soil temperature?

Increased water content increases the specific heat of the soil, increasing the amount of heat needed to raise the soil temperature a given amount. It also increases the rate of evaporation, with increases the rate at which heat is removed from the soil by evaporation (heat of evaporation). Increased water content also increases the thermal conductivity so that heat absorbed at the surface is more readily transmitted deeper.

50. Which conducts heat more readily, a dry soil or a wet soil?

See # 49.

51. Two soils are identical in all respects except that soil A has a volumetric water content of 0.2 whereas soil B has a water content of 0.4. Which soil warms faster?

The one with the lower water content, soil A (see # 49).

52. Compare the daily temperature variation at a depth of 2 cm to the daily temperature variation at a depth of 30 cm in soil.

The diurnal variation in temperature is greater at the surface, higher high, lower low. Also, the timing of temperature maxima and minima are different at 2 cm and at 30 cm depth. The extremes occur later at 30 cm than at 2 cm. This is a matter of heat conduction into and out of the soil.

53. Compare the season temperature variation at a depth of 2 cm to that at a depth of 30 cm in soil.

This is similar to daily variation, with greater range in temperature at 2 cm than 30 cm and annual cycles offset somewhat.

54. What is the effect of a surface mulch (including crop residues in conservation tillage) on soil temperature?

It insulates the soil, moderating temperature compared to bare soil.